



**UNIVERSITI PUTRA MALAYSIA**

**THE DESIGN OF CRUDE PALM OIL CLARIFIER**

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# **THE DESIGN OF CRUDE PALM OIL CLARIFIER**

**By**

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**Thesis Submitted in the Fulfillment of the Requirement for the  
Degree of Master of Science in the Faculty of Engineering,  
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## LIST OF ABBREVIATIONS

$a_a$	Pre-exponential factor for the Arrhenious equation
$a_e$	External acceleration
$a_v$	Specific surface
$A$	Area
$A_p$	Maximum projection area
$A_u$	Underflow output area
BOD	Biological Oxygen Demand
$C$	Concentration
$C_D$	Drag coefficient
$C_f$	Oil content in fresh feed
$C_r$	Oil content in recycle
$C_l$	Concentration of the limiting layer
$C_o$	Initial concentration
COD	Chemical Oxygen Demand
$C_u$	Underflow concentration
CPO	Crude Palm Oil
$d_d$	Diameter of drop
$d_{di}$	Mean drop diameter
$d_{do}$	Initial drop diameter
$d_a^*$	Drop diameter at the coalescence interface
$d_p$	Diameter of particle
$dv/dt$	Acceleration of the body
$D$	Depth of the sedimentation tank



DOC	Dissolved organic compounds
$E_{av}$	Activation energy
$f_e$	Porosity ratio
$F$	Fresh feed
$F_b$	Buoyancy force
$F_d$	Drag force
$F_e$	External force
$F_p$	Flux of the settling particle
$F_u$	Flux to provide bulk flow of the underflow
$h_c$	Sludge interface height
$h_p$	Dense-packed height of batch system
$h_s$	Sedimentation height of batch system
$h_{\infty}$	Ultimate sludge interface height
$H$	Height of dispersion
$H_c$	Height of the compression zone at critical concentration
$H_p$	Dense-packed height
$H_s$	Sedimentation height
$H_{\infty}$	Height of the compression zone at infinite time
$k$	Constant
$L_o$	Input volumetric flow rate
$L_u$	Underflow volumetric flowrate
$m$	Mass of particle
$M_l$	Mass of liquid in the compression zone
$M_s$	Mass of solids in the compression zone

$n$	Power law exponential constant
$n'$	The average number of $n$ for the measured temperature range
$N$	Number of drops
NOS	Non Organic Solids
$Q_o$	Recovered oil
POME	Palm Oil Mill Effluent
PORIM	Palm Oil Research Institute of Malaysia
$Q_c$	Continuous throughput
$Q_d$	Dispersion phase throughput
$r$	Radius of centrifugal path
$R$	Gas constant
$Re^*$	Power law Reynold's number
$S_{ij}$	Sedimentation coefficient
$ST$	Surface Tension
$t$	Time needed to drops to reach the coalescence interface
$t_c$	Critical time
$t_L$	Time of the limiting layer reaching the interface
$t_o$	Incubation time needed for the drop to grow from zero to $d_{do}$
$t_p$	Thickness of plates
$t_u$	Underflow time
$T$	Temperature
$v$	Velocity
$v_i$	Settling velocity of solid particles
$v_h$	Velocity of discrete particle in a cloud of similar particles

$v_r'$	Rising velocity of the layer
$V$	Volume
$V_o$	Surface loading rate without plates
$V_o'$	Surface loading rate with plates
$w$	Width distance
$X_f$	Mass fraction of the feed
$Y_i$	volume rate of coalescence per unit area
$Z_c$	Critical height
$Z_l$	Height of the interface at $t_l$
$Z_o$	Initial height
$Z_u$	Underflow height

*Greek letters*

$\alpha$	Angle of inclination
$\varepsilon_l$	Hold-up at the coalescence interface
$\varepsilon'$	Mean hold-up
$\varepsilon^*$	Hold-up at coalescence interface
$\phi_j$	Volume fraction of particle j
$\gamma$	Shear rate
$\gamma_i$	Shape factor
$\eta_a$	Apparent viscosity
$\lambda$	Diameter ratio
$\mu$	Viscosity
$\rho_f$	Density of fluid

$\rho_j$	Density of particle species j
$\rho_l$	Density of liquid
$\rho_p$	Density of particles
$\rho_s$	Density of solids
$\tau$	Shear stress
$\tau_b$	Instantaneous binary coalescence
$\tau_{bo}$	Binary coalescence for drops of initial diameter
$\tau_b^*$	Binary coalescence for drops of reference diameter
$\tau_i^*$	Coalescence time at the coalescence interface
$\omega$	Angular velocity

Abstract of Thesis Submitted to the Senate of Universiti Putra Malaysia in Fulfillment of  
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## THE DESIGN OF CRUDE PALM OIL CLARIFIER

By

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May, 1998

Chairman: Associate Professor Dr. Ir. Tan Ka Kheng

Faculty: Engineering

The objective of this research was to study the settling characteristics of crude palm oil (CPO), and use them to design a crude palm oil settler so that to increase the oil recovery, and hence the oil loss in the effluent can be minimized.

The apparent viscosity ( $\eta$ ) of CPO after dilution with water was measured and an equation for its behaviour with shear rate ( $\gamma$ ) and temperature ( $T$ ) was derived:

$$\eta = 898 \exp (1900/T) \gamma^{(-0.61)}$$

The equation was used to model CPO settling. Two approaches to determine the design criteria of the CPO settler were followed - conventional solid/liquid analysis, as proposed by Lim (1977), and liquid/liquid analysis. The liquid/liquid analysis

underestimated the required settler height by 38-53%, and the conventional approach by 55-63%. Finally, a coagulation Jar test was carried out to examine the effects of five coagulants in the oil recovery from the effluent. The results showed that the use of coagulant can reduce oil loss in the clarifier. The recovered oil was 3% of the plant throughput.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia  
sebagai memenuhi keperluan untuk ijazah Master Sains.

## REKABENTUK PENULINAN MINYAK SAWIT MENTAH

Oleh

SULAIMAN A. S. AL-ZUHAIR

May, 1998

Pengerusi: Professor Madya Dr. Ir. Tan Ka Kheng

Faculti: Kejuruteraan

Objektif penyelidikan ini ialah untuk mengkaji ciri-ciri CPO (minyak sawit mentah), dan menggunakannya untuk menentukan rekabentuk “settler” untuk minyak sawit mentah dan mengurangkan kehilangan minyak dalam pengaliran air yang mengandungi bahan buangan.

Kelikatan minyak sawit mentah selepas penulinan disukat dan persamaan yang menentukan perbezaannya dengan tahap kejelasan dan suhu ditentukan oleh  $\eta = 898 \exp(1900/T) \gamma^{(-0.61)}$ . Persamaan ini boleh disyorkan untuk digunakan dalam “CPO settling models”. Dua cara untuk mencari ciri-ciri rekabentuk “CPO setteler” adalah seperti berikut, pertama ialah cara analisis pepejal/cecair menghasilkan kurang anggaran

tinggi “setteler” sebanyak 38-53%, manakala keputusan cara konvensional menghasilkan 55-63% kekurangan daripada anggaran. Akhirnya ujikaji bikar pemejalan dijalankan untuk memeriksa kesan penambahan lima jenis pemejal dan keputusan ujikaji menunjukkan bahawa penambahan ini mengurangkan kehilangan minyak di dalam penulin. Minyak yang dapat diperolehi ialah 3% daripada jumlah minyak yang dihasilkan.



## CHAPTER I

### INTRODUCTION

When first expressed from the fruits, palm oil (a product even more crude than the commercial *crude palm oil*) is dirty and unpalatable, containing water, soluble impurities and a considerable amount of debris. The composition of the oil straight from the screw press is 40% - 75% oil, 10% - 40% water and 6% - 25% non-organic solids (NOS).

To remove the impurities, the oil is stood in a clarifier where the oil and water (together with most of the debris), being immiscible liquids, separate out. The heavier water and debris settle to the bottom while the relatively clean and dry oil rises to the top and is skimmed off.

The design of the clarifier is very important as it is a major wastewater producer. However, the laws of settling, such as Stokes law, cannot be easily applied to it because the sizes, shapes and densities of the solid particles are so variable. In addition, water is present as a third confounding factor in the system.

The main design parameters used today are determined empirically (PORIM, palm oil factory process handbook, 1988). This is neither scientific nor economically efficient.